

MODIS Science Team Member
Semi-Annual Report
(Jan - Jun 2000)

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FOCUS ACTIVITIES DURING THE REPORTING PERIOD

The most important activities undertaken during this reporting period are the following:

1. Land surface reflectance code development, testing and delivery.
2. MOD09 - QA activities.
3. MOD09 Validation activities
4. Radiative Transfer modeling.
5. AVHRR/MODIS Middle Infrared surface reflectance
6. MODIS Adaptive Processing System (MODAPS)/PI Processing/250m system

1. Land surface reflectance code development, testing and delivery

- A. Corrections done to the code for compositing level 3 land surface reflectance from level 2G land surface reflectance products (MOD_PR09A, or PGE 21): tested the code extensively and delivered several versions of the code, which can process 500m-resolution and/or 250m resolution data.
- B. Several corrections were done to the code for generating orbital level 3 aerosol optical thickness (AOT) data from level 2 AOT granules (MOD_PR04ORB, or PGE 05).
- C. Several corrections were done to the code for generating level 2 land surface reflectance and thermal anomaly products (MOD_PR09, or PGE 11): adapted the code such that two distinct internal cloudmasks can be generated, one for the reflectance product, one for the thermal anomaly product; implemented algorithms for handling dead detectors (individual scan lines in the L1B input that contain nothing but fill data); upon visual inspection of the L1B input, determined that detectors 2 and 6 of band 6 and detector 13 of band 7 were dead, and hard-coded their designation as dead in the program. Also adapted the Level 2 not to use the 250m cloud mask data.
- D. Wrote the official users guide for the land surface reflectance products, for level 2 data, level 2G data and level 3 data (see <http://modis-land.gsfc.nasa.gov/MOD09/>, Surface Reflectance Users Guide); however, so far only the level 2 users guide is complete.

2. Global Analysis of MODIS surface reflectance first results

We conduct our global analysis based on the coarse resolution reflectance product (MOD09CRS) which is pushed automatically to our SCF each time PGE11 is run in MODAPS. This product and the associated level 3 coarse resolution (MOD09A1CRS) are also used by LDOPE to produce global browse data set which are available on line (<http://modland.nascom.nasa.gov/browse/8day.cgi>). This data set enabled us to produce composites over longer period of time and check the aerosol correction approach as well as the overall quality of the product. An example of one of the composite produced is presented in figure 1. The product is also used to generate vegetation indices (EVI and NDVI) such as the ones presented in figure 2,3. The color scales has been adjusted to facilitate the comparison of NDVI and EVI. We can notice the lower values of NDVI over vegetation area in the presence of haze (Brazil, Indonesia) that do not appears on EVI. We also compared more quantitatively the two indices for a variety of land covers over Africa. Figure 4 shows that NVDI and EVI are generally well correlated. For higher values of the indices, corresponding to denser vegetation, EVI exhibits more variability suggesting a better sensitivity at high Leaf Area Index values.

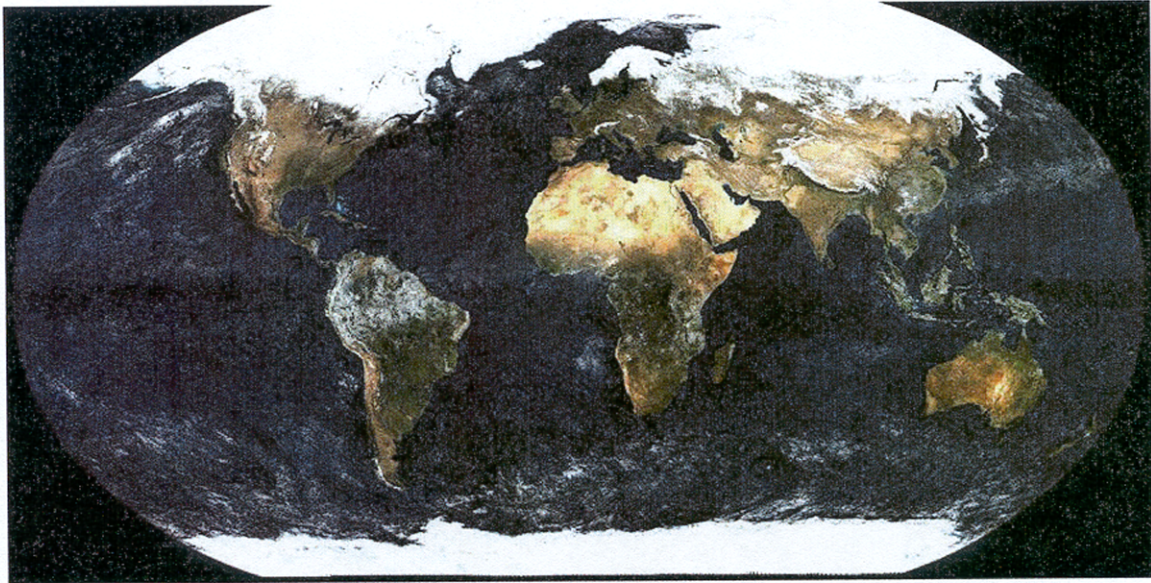


Figure 1: True Color MODIS Surface Reflectance Minimum Blue Composite RGB, Red=MODIS band 1, Green=MODIS band 4, Blue=MODIS band 3, March 17, 2000 to April 10, 2000 Period.

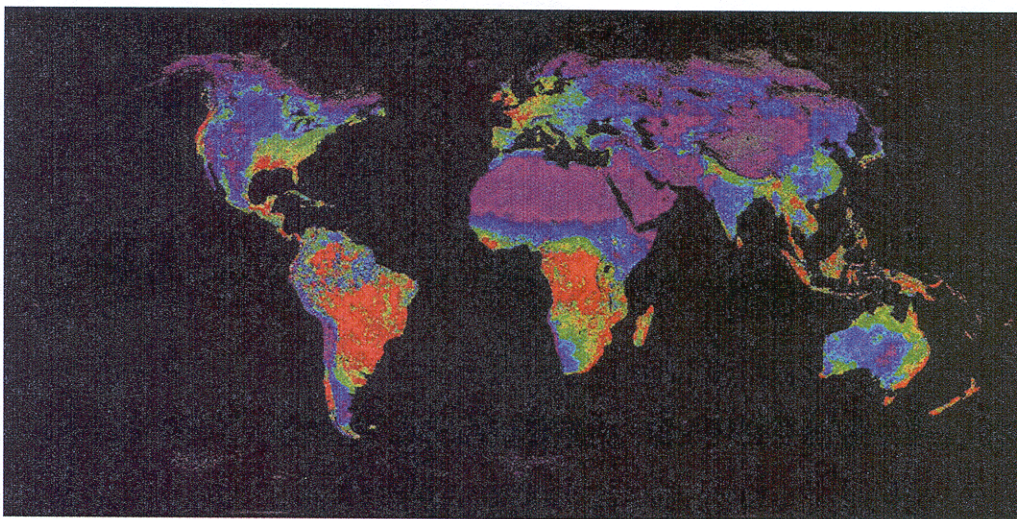


Figure 2: NDVI generated from the composite presented in figure 1.

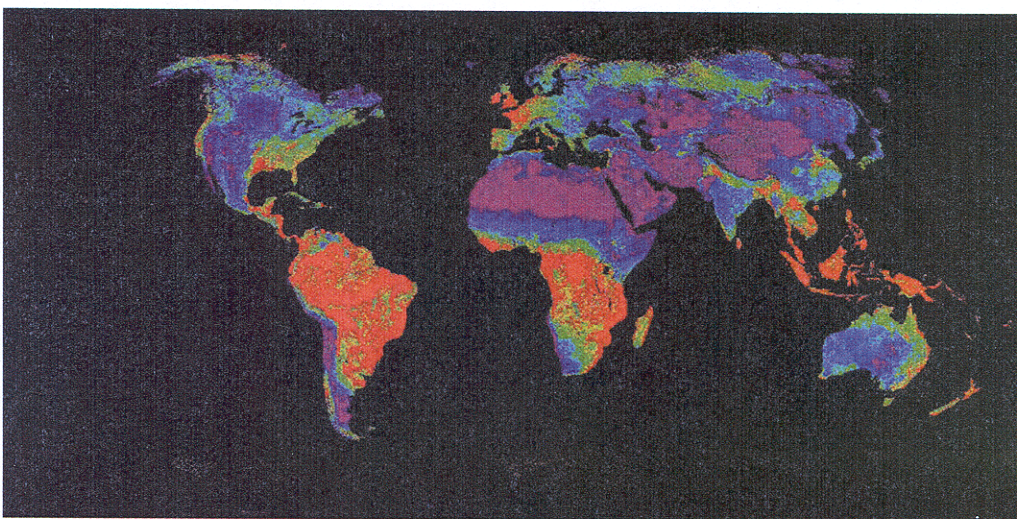


Figure 3: NDVI generated from the composite presented in figure 1.

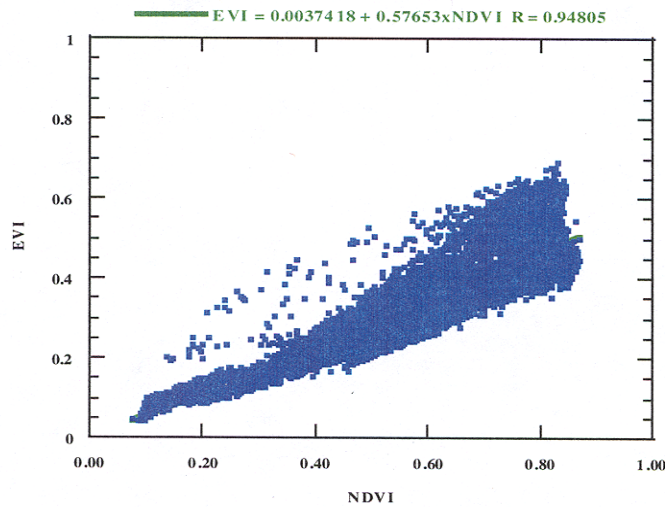


Figure 4: Comparison of NDVI and EVI values over Africa.

3. Comparison of MODIS and AVHRR 1km data

We also evaluated the MODIS first data set with respect with pre-cursor data sets such as AVHRR. Figure 5 shows a comparison between color composites obtained from AVHRR 1km and MODIS data over the Eastern United States. We extracted a clear area from figure 5 and enlarged it illustrate the enhanced spatial resolution (250m) available on MODIS band 1 and 2. (Figure 6) We also compared the NDVI derived from the AVHRR 1km data processed by the Pathfinder II processing system with MODIS NDVI, the VI were re-scaled to make them comparable since MODIS NDVI is higher than AVHRR. The near-infrared band on MODIS (band 2) is narrower than on AVHRR, therefore the peak of vegetation will give a higher reflectance on MODIS than it will on AVHRR. This higher reflectance observed by MODIS for vegetation is illustrated by Figure 8, where we plot for different land covers the reflectance observed by MODIS and AVHRR.

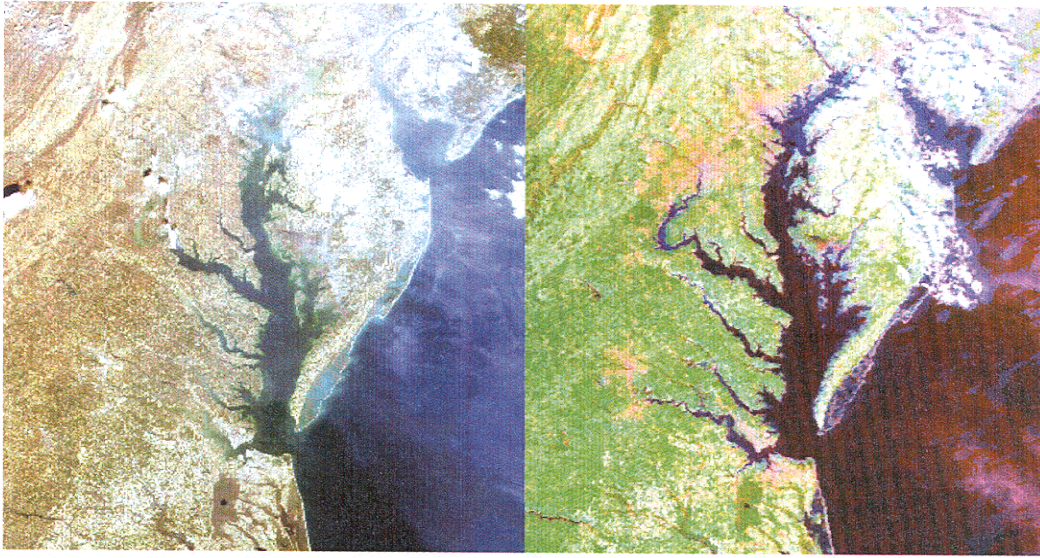


Figure 5: Comparison of AVHRR 1km data (right) with MODIS data acquired over Eastern United States MODIS is a true color composite based on Red=band 1(670nm),Blue=Band 3 (470nm) and Green=Band 4 (555nm), AVHRR is based on Blue=band 1 (670nm),Green= Band 2 (870nm) and Red=Band 3 (3750nm reflective component).

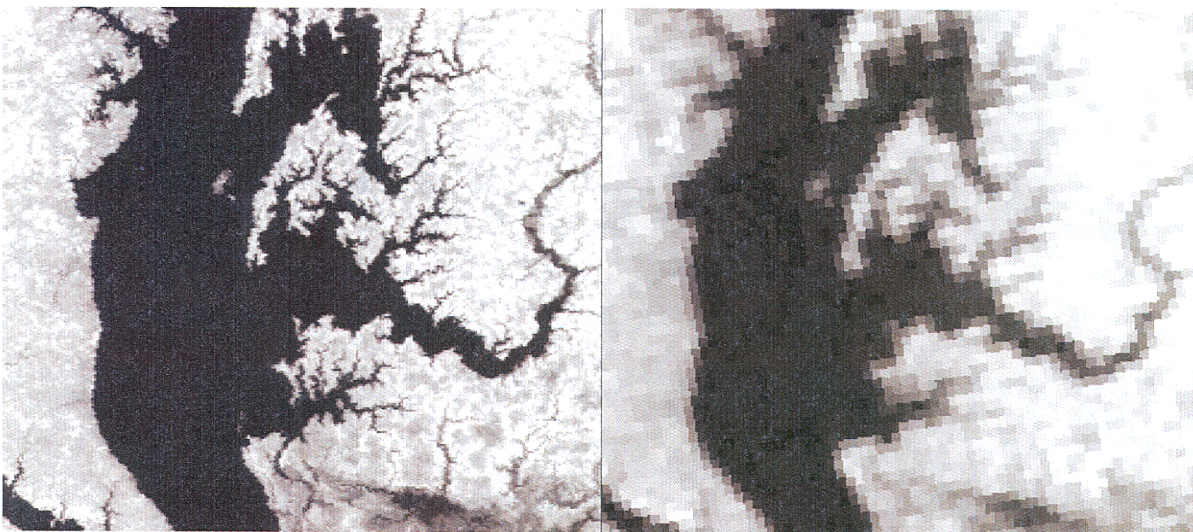


Figure 6: Comparison of MODIS Band 2 (870nm) at 250m with AVHRR band 2 (870nm) at 1km.

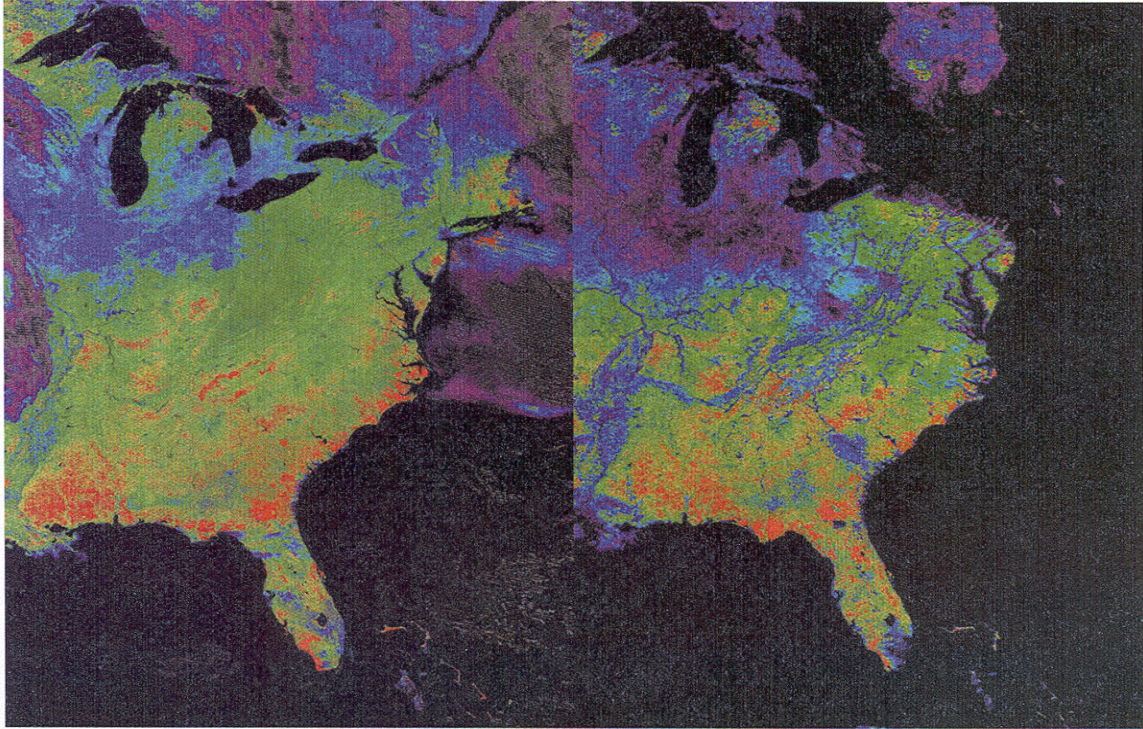


Figure 7: Comparison of MODIS NDVI (Left) with AVHRR NDVI (Right), the color scale were adjusted to match respective dynamic range.

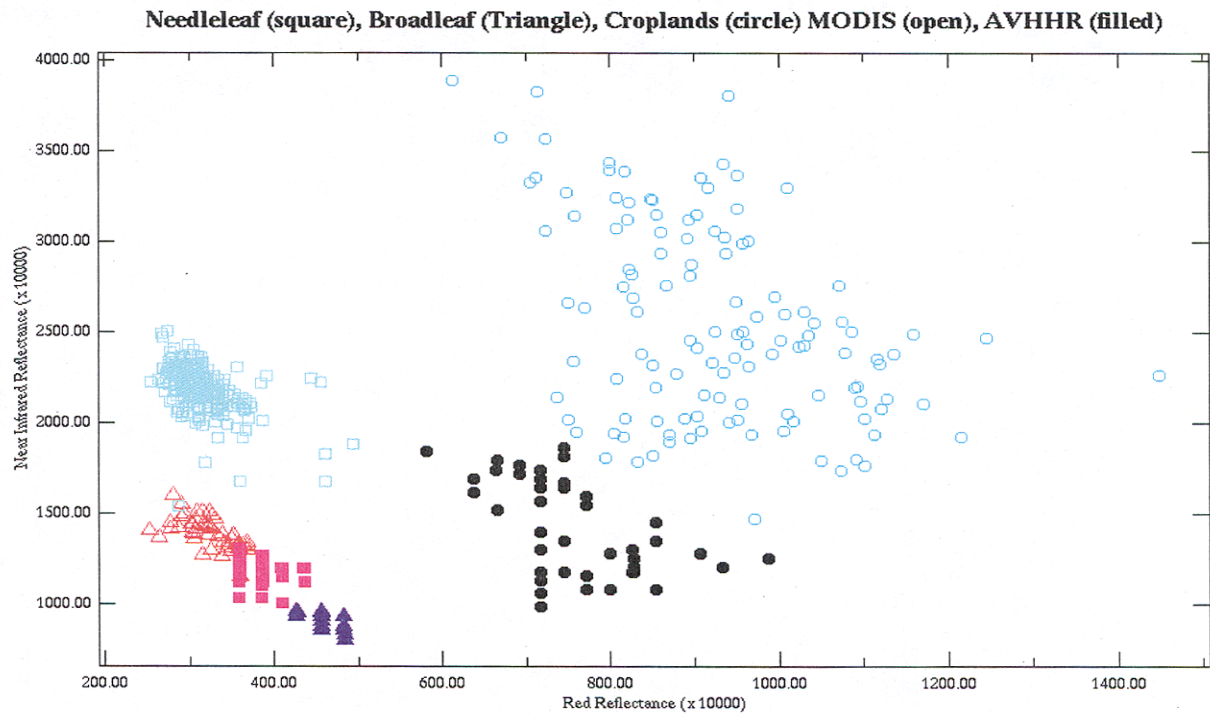


Figure 8: Comparison of MODIS and AVHRR red/near infrared reflectance for selected target over Eastern United States.

4. MODIS aerosol correction

Using the coarse resolution product, we were able to prototype the operational aerosol correction which is a unique feature of the MODIS atmospheric correction algorithm. We tested the correction on the global data set and generate a composite product for the April,24,2000 to May 23, 2000 period. Figure 9a shows the true color image of the surface reflectance without aerosol correction, Figure 9b shows the global product with aerosol correction. Figure 10 shows a detail over China where it is particularly hazy during the whole compositing period. This test shows the importance of the aerosol correction and the improvement of the data after correction. Moreover, the good agreement of the MODIS aerosol optical thickness over land (Figure 11) with the sun photometer data from AERONET shows that the input product used for correction is within the expected error bars.

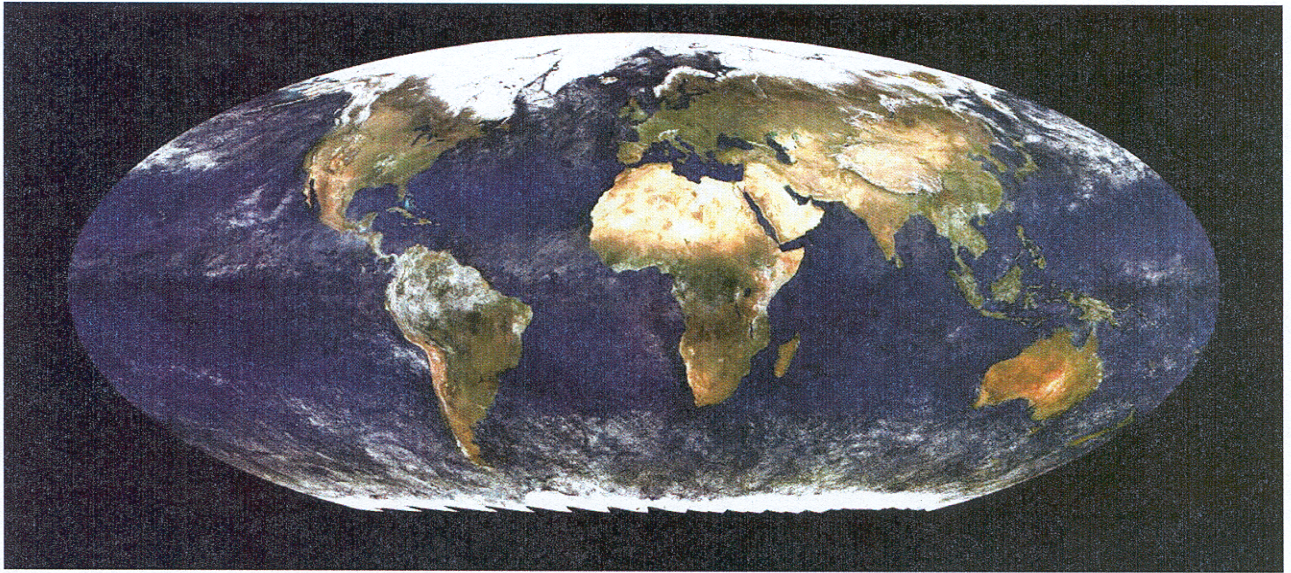


Figure 9a: True color image of the composite (April 24,2000 to May 23, 2000) of the MODIS surface reflectance product without aerosol correction.

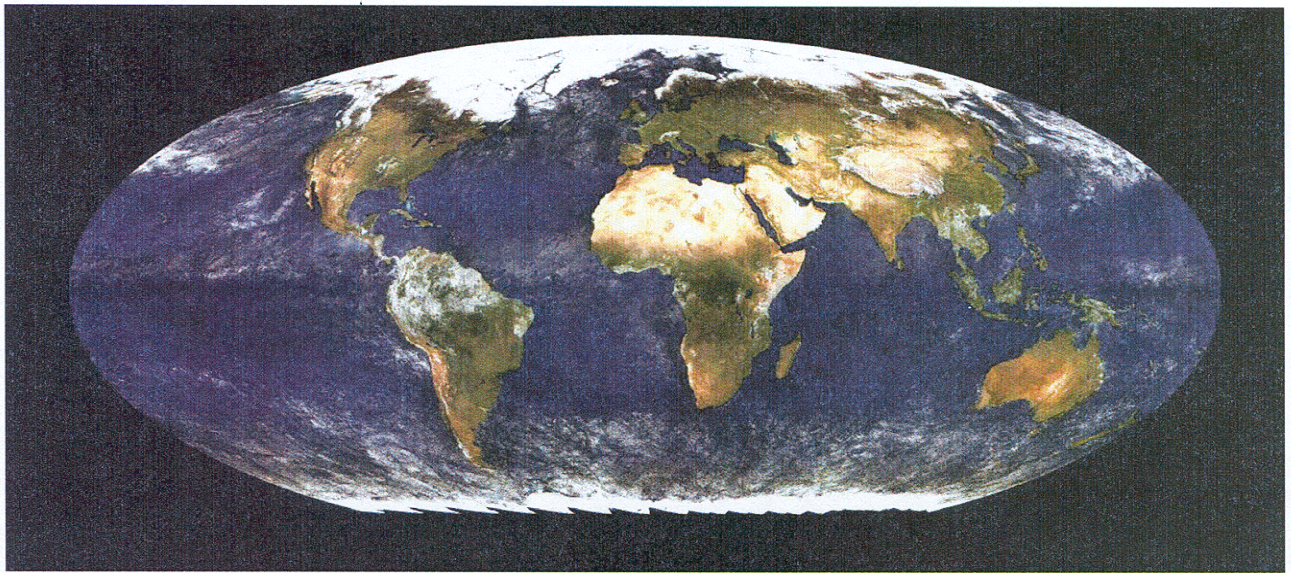


Figure 9b: True color image of the composite (April 24,2000 to May 23, 2000) of the MODIS surface reflectance product with aerosol correction.



Figure 10: Comparison of the aerosol corrected data (right) with no aerosol corrected data (left) over China.

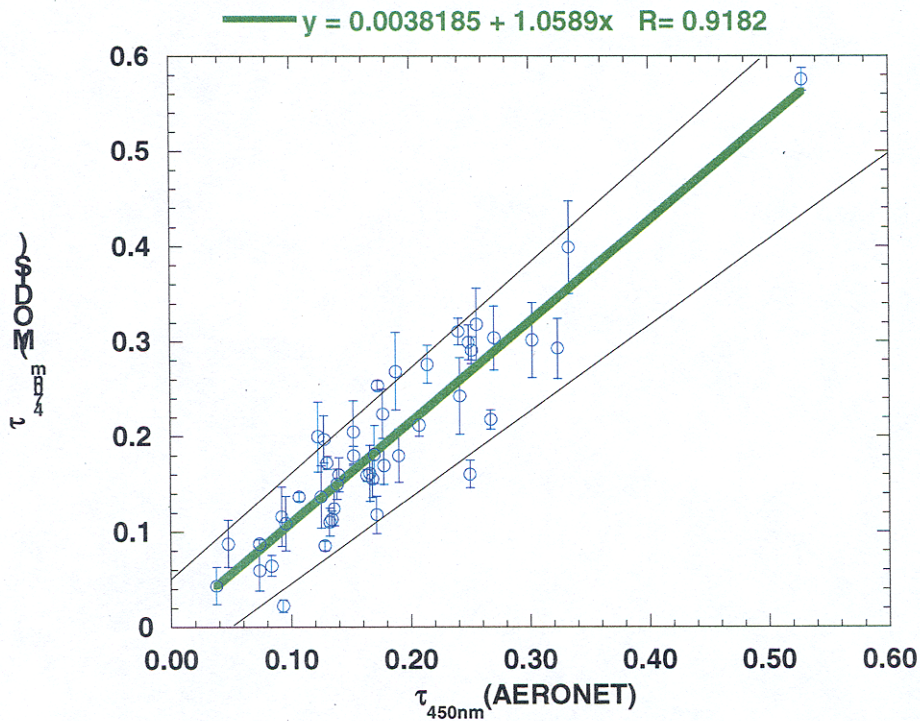


Figure 11: Comparison of the aerosol optical thickness over land derived from MODIS in Band 3 (470nm) with the AERONET data.

5. AVHRR/MODIS Middle infrared surface reflectance

MODIS surface reflectance is one of the key products in the MODIS LAND processing chain. MOD 09 performs atmospheric corrections and produces surface reflectances in the visible and near infrared spectrum. This work is aimed to extend MODIS surface reflectance product to the middle infrared atmospheric window (3.5 - 4 μ m), i.e. MODIS bands 20, 21, 22 and 23.

Retrieval of middle infrared surface reflectance

The two major difficulties in the retrieval of middle infrared surface reflectance are the estimation of thermal emission from the surface and the correction of atmospheric perturbations. In the middle infrared, thermal emission from the surface is in the same order of magnitude as the solar reflected radiance. Thermal emission depends on surface temperature and emissivity. Surface temperature is derived from at least one of the MODIS thermal infrared bands (bands 29, 31 and 32). Surface emissivity is taken into account by means of ratios of spectral emissivity in middle infrared bands and in thermal infrared bands. Such emissivity ratios are deduced from night images. This method to assess the middle infrared surface reflectance requires measurements in MODIS bands 20 to 23, 29, 31 and 32 during day and night. For atmospheric correction purposes, split-window techniques, commonly used in thermal infrared, cannot be applied because spectral information of each MODIS band needs to be preserved. Each measurement in each MODIS bands considered here must be corrected from molecular absorption, atmospheric thermal emission and molecular and aerosols scattering. These perturbations are estimated using MODTRAN radiative transfer code and a description of the atmospheric profile.

Atmospheric corrections

NOAA National Center for Environmental Prediction provides the MODIS processing system with global atmospheric data in near real time. These data are derived from global circulation model inputs every 6 hours on a 1 degree by 1 degree grid. Four times a day, atmospheric data are stored in a single file under GRIB format. They include, among

many other parameters, air temperature, relative humidity and geopotential height for 27 pressure levels. The GRADS software is used to extract atmospheric profile at a given time and location.

Observation conditions complete the atmospheric profile to prepare for the radiative transfer computation. For each level1B data granule, sensor and solar angles are retrieved from the level1B geolocation fields (MOD03) every degree in latitude and longitude. Then, all atmospheric profiles and corresponding observation conditions within the area covered by a granule are put together in a single MODTRAN input file.

The MODTRAN radiative transfer code (version 4) has been adapted to give as direct results all the atmospheric parameters needed in all MODIS bands considered. Atmospheric parameters designate the total transmittance and the atmospheric emitted radiances toward the sensor and the target. In the case of day time images in the middle infrared, direct solar irradiance of the target and solar radiance scattered by the atmosphere toward the sensor and the target are also computed. All atmospheric parameters are integrated over sensor response of each MODIS bands considered.

Atmospheric parameters are now available on a 1 degree regular grid within a granule. However, radiances in MODIS emissive bands are only available in level1B format, with no projection of any kind. An image projection issue is raise here. This is the last step before atmospheric parameters can be applied to measured radiances in order to produce atmospherically corrected radiances in middle and thermal infrared bands.

Geographic projection

A specific projection tool has been developed to transform level1B format into geolocated images in geographic projection - latitude and longitude samples are constant all over the image. MOD03 geolocation fields provide latitude and longitude coordinates of each level1B pixel. This software allows the projection of all MODIS emissive bands from MOD021KM data, as well as sensor and solar angles (zenith and azimuth) from MOD03 data, cloud mask from MOD35L2 and MODIS Sea Surface Temperature from MOD28L2.

A pixel of a projected image represents an area of 0.01 degree by 0.01 degree in latitude and longitude. For most continental areas, this is approximately a square of 1 by 1 km, close to the nominal spatial resolution of MODIS for nadir observations. During the projection, no interpolation is performed but a simple nearest neighbor method is applied. Projected images compare to coastlines derived from digital elevation model with good agreement. Using linear interpolation, atmospheric parameters, available on a 1-degree regular grid, are downsampled to images with the same resolution as sensor level radiances (0.01 degree) using bi-linear interpolation. Then, ground level radiances are produced on a pixel basis.

Validation of atmospheric corrections

Before going further in the retrieval of middle infrared reflectance, atmospheric corrections need to be validated for two reasons. First, to be sure all data and software involved in the atmospheric correction scheme are well handled and, second, to assess the quality of ground level radiances for further error assessment on middle infrared reflectance.

Two validation activities were performed. The first one focuses on the total water vapor content of the atmospheric column to check if atmospheric data are properly handled. Water vapor is the main absorbing component of the atmosphere regarding radiation in middle and thermal infrared. The second validation activity was a comparison between brightness temperatures obtained over sea in each MODIS bands after atmospheric corrections and MODIS Sea Surface Temperature products.

AERONET is a global network of sun photometers that is dedicated to aerosols characterization. Total water vapor contents of the atmospheric column are also derived from sun photometers measurements and are available through the AERONET web site (aeronet.gsfc.nasa.gov:8080). Four sites in Southern Africa were selected: Bethlehem (28.248S; 28.333E), Inhaca (26.041S; 32.905E), Mongu (15.254S; 23.151E) and Skukuza (24.992S; 31.587E) and water vapor data were collected for June 2000. Each of these water vapor contents is compared to total water vapor content derived from atmospheric profile (the closest in space and time). Figure 12 shows good agreement between the two data sets with a standard deviation of 0.324 g.cm⁻².

MODIS Sea Surface Temperature products (MOD28L2) include two measurements of the SST: one using MODIS thermal infrared bands (31 and 32) and another one using middle infrared bands (20, 22 and 23). Both SST's are derived using split-window methods. Comparison between brightness temperatures and sea surface temperature gave us a better idea of the accuracy of atmospheric corrections. Sea level radiances in each band are corrected from spectral emissivity effect and converted into brightness temperatures using the central wavelength of each band. Brightness temperatures and SST's are collected for several locations in the seas surrounding the southern African coast. Time period ranges from mid June 2000 to mid July 2000.

In general, brightness temperatures found in bands 20, 22, 23, 29 and 31 are in good agreement with split-window SST's from thermal infrared bands with a standard deviation equal to 1.07, 1.33, 1.27, 1.88 and 1.96 degree respectively (see Figures 13a-g). For comparison, a standard deviation of 1.27 has been found between thermal and middle infrared SST's. The accuracy of brightness temperatures in bands 21 and 32 is not so good. For band 21, the instrumental noise is much higher than other middle infrared bands ($\text{Ne}\Delta T$ is 2 degrees at 335K). Band 32 is at the end of the atmospheric window in the thermal infrared and is more sensitive to water vapor than any other MODIS band considered here. Accuracy of brightness temperatures in band 32 is limited by uncertainties on water vapor content of the atmosphere.

Biases between brightness temperatures and SST's in middle infrared bands (20, 22, 23) are lower than those in thermal infrared bands (29, 31, 32). Such biases are mainly due to inaccurate corrections from spectral emissivity effect. At a temperature of 300K, a variation of 1% of the spectral emissivity would impact for 0.6 degree the brightness temperature in thermal infrared and for 0.25 degree the brightness temperatures in middle infrared.

Conclusion

In preparation for the retrieval of middle infrared surface reflectance with MODIS data, atmospheric corrections of measurements in MODIS middle and thermal infrared bands (20, 21, 22, 23, 29, 31 and 36) are now operational. Atmospheric perturbations are

computed using a radiative transfer code fed by atmospheric profiles extracted from a global atmospheric data set. A specific projection tool has been developed, allowing for the correction of atmospheric perturbations on MODIS level1B data. Atmospheric corrections have been validated with promising results regarding the accuracy of middle infrared surface reflectance. Projection of level1B data will allow comparison between day and night data and mosaicking. As an illustration, Figure 14 shows a composite image of the maximum of ground level temperature during night in Band 31 over southern Africa during a period of one month.

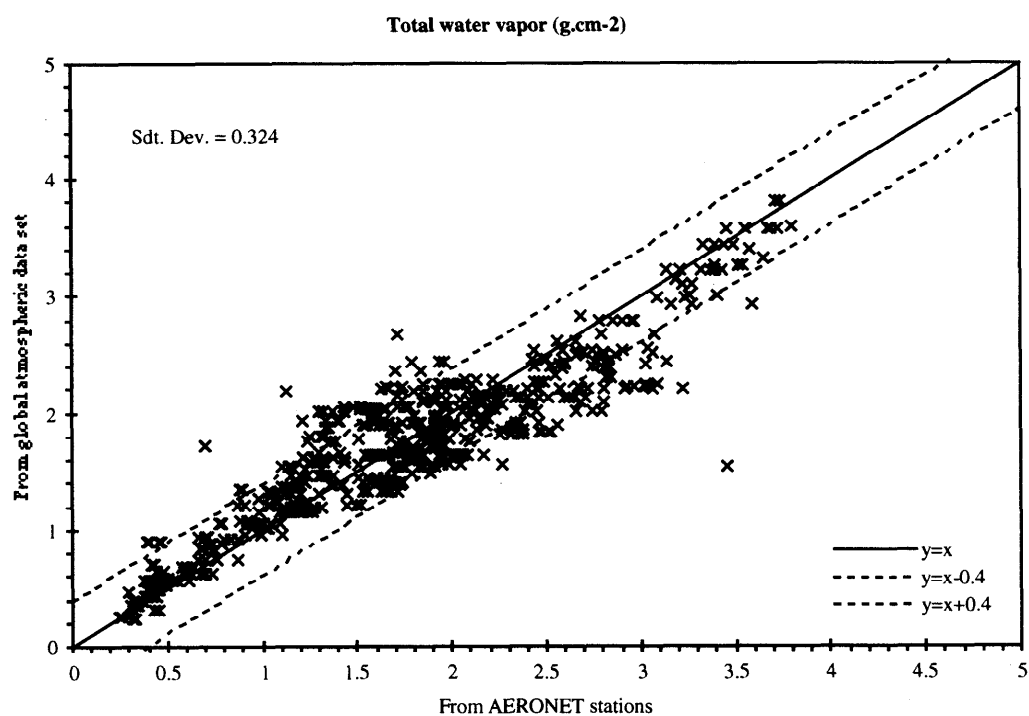


Figure 12: comparison between total water vapor content of the atmospheric column as given by AERONET stations and derived from the global atmospheric data set.

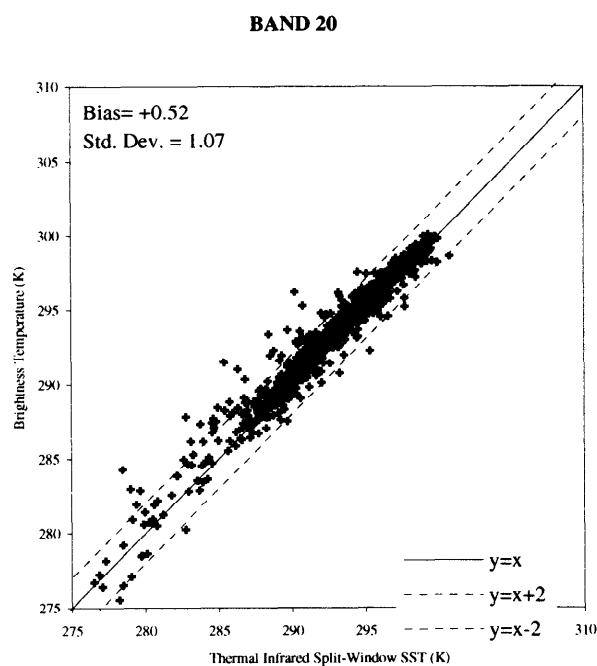


Figure 13a: comparison between split window sea surface temperature (MOD28_L2) and sea level brightness temperature in MODIS band 20.

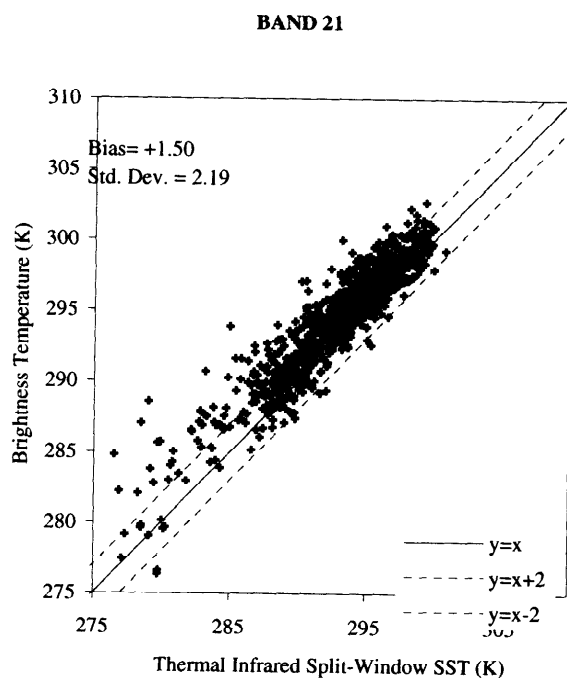


Figure 13b: comparison between split window sea surface temperature (MOD28_L2) and sea level brightness temperature in MODIS band 21.

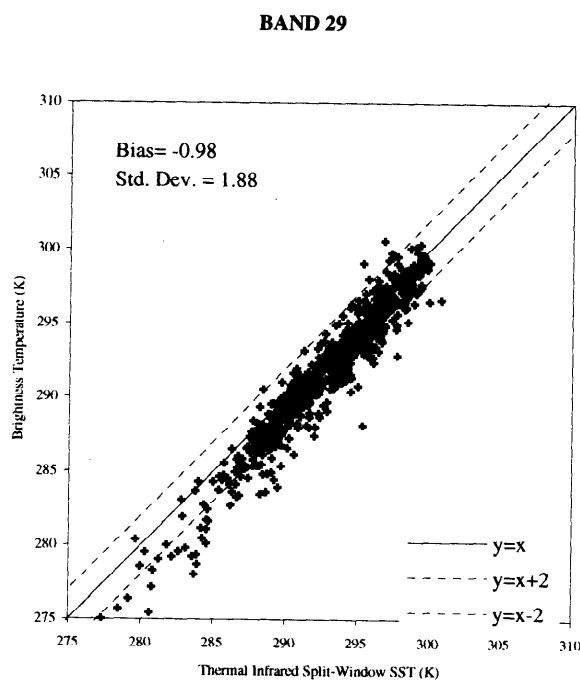


Figure 13c: comparison between split window sea surface temperature (MOD28_L2) and sea level brightness temperature in MODIS band 29.

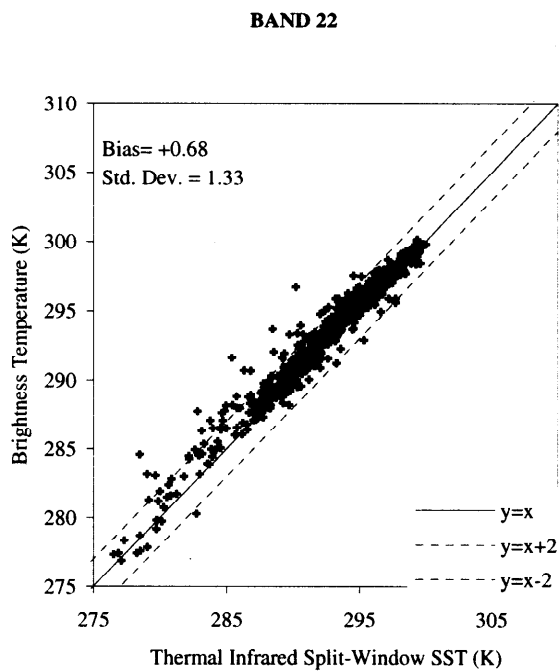


Figure 13d: comparison between split window sea surface temperature (MOD28_L2) and sea level brightness temperature in MODIS band 22.

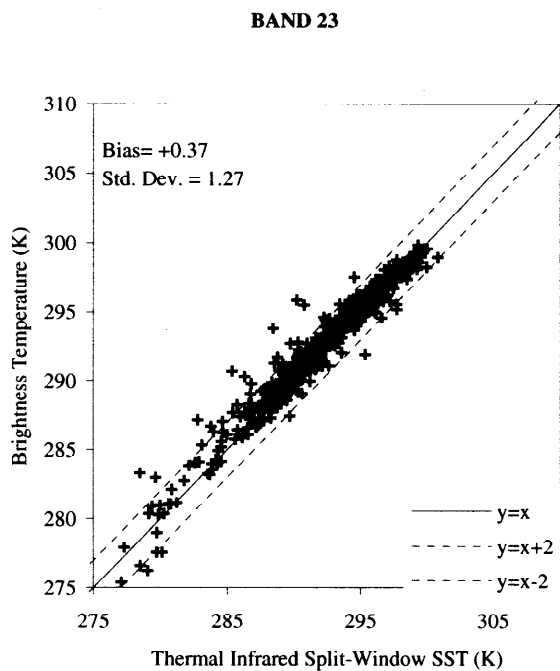


Figure 13e: comparison between split window sea surface temperature (MOD28_L2) and sea level brightness temperature in MODIS band 23.

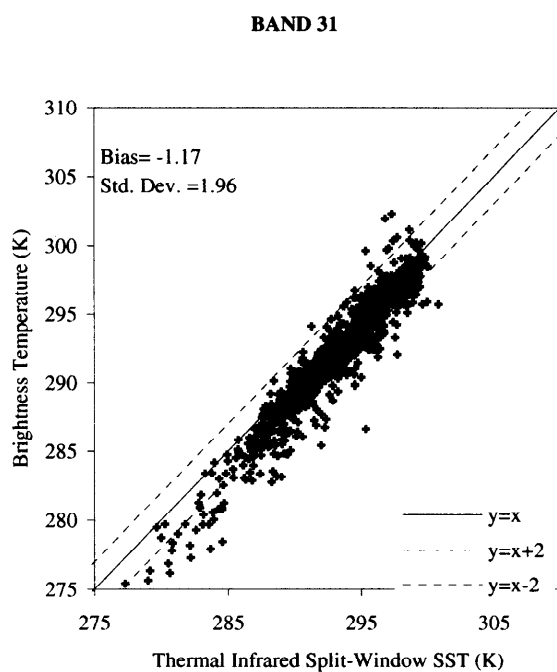


Figure 13f: comparison between split window sea surface temperature (MOD28_L2) and sea level brightness temperature in MODIS band 31.

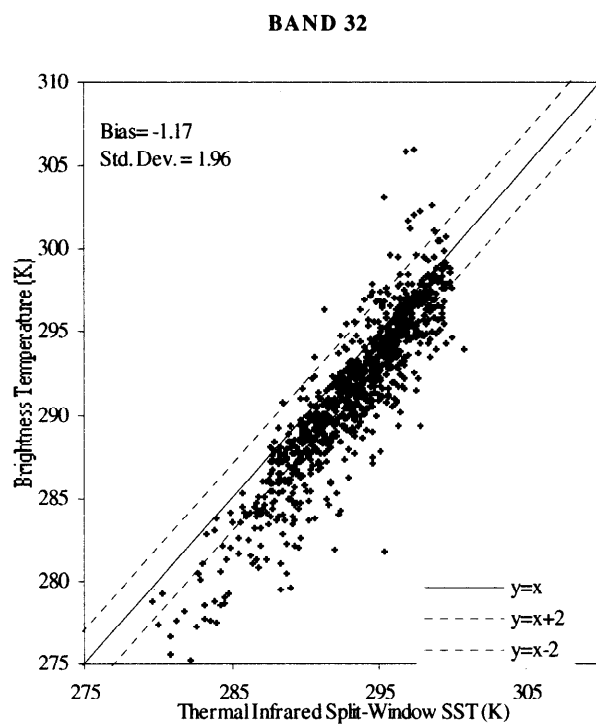


Figure 13g: comparison between split window sea surface temperature (MOD28_L2) and sea level brightness temperature in MODIS band 32.

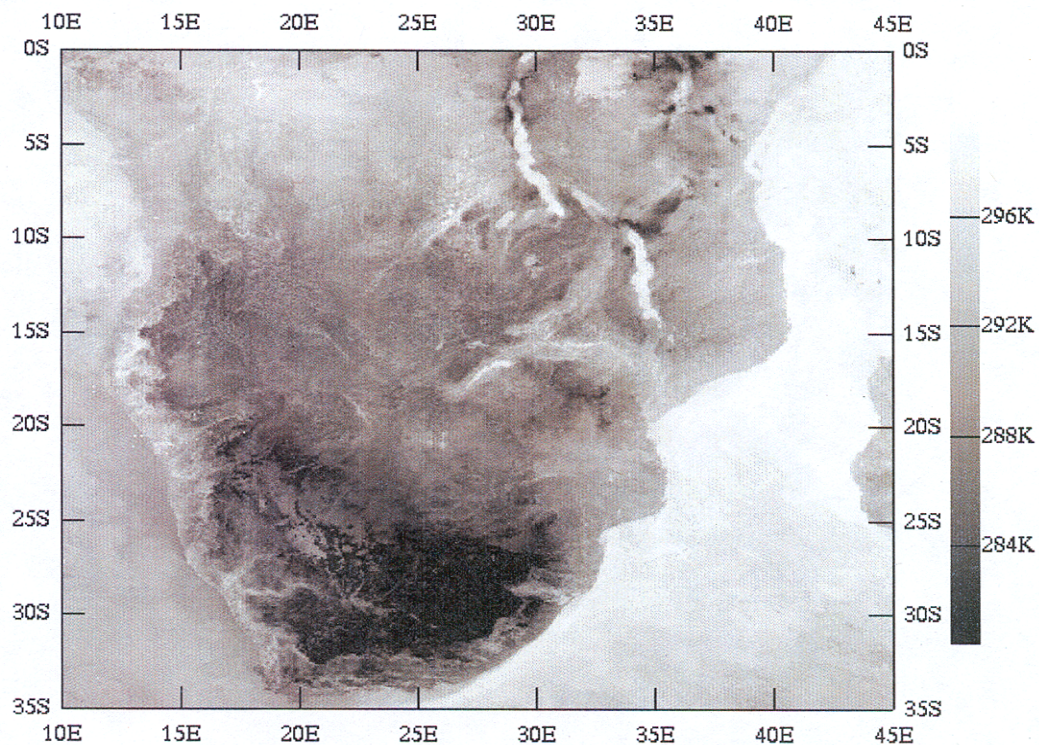


Figure 14: composite image of maximum MODIS band 31 brightness temperature during night after atmospheric corrections (period: 23 June – 23 July 2000).

6. MODIS Adaptive Processing System (MODAPS) / PI Processing /250m system

The Land surface reflectance SCF remains actively involved in the PI-led processing activity ranging from making sure that PIs' needs are accurately perceived by the MODAPS development team and by management to participating in the development of the processing system and various phases of testing.

The SCF participated in the weekly PI-Processing meetings where Eric Vermote represented the land group.

The SCF also participated in all of the weekly MODAPS meetings/telecons where problems were discussed to identify solutions and where progress in the new development was tracked.

Following the SWAMP recommendation to ensure the production of global MODIS data, our SCF participated in the discussions to identify alternatives to the 0.5X MODAPS original production plan. The solution that was adopted was to take the production of the 250m out of MODAPS. A completely independent system generates 10% of the 250m land surface reflectance and VI's so as to provide some data for the PI's to evaluate (see <http://modis-250m.nascom.nasa.gov/>). Our SCF played an important role in the shaping of this proposal and in building the prototype production system.

A. MEETINGS ATTENDED

- MODIS Science Team Meeting, June, 2000.
- Weekly PI Processing Status Meetings, NASA/GSFC.
- Weekly Technical Team Meetings, NASA/GSFC.
- Weekly MODIS L1 Integration Meetings.
- Weekly SDDT (Science Data Discipline Team) Meetings.